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ABSTRACT

This study investigated whether Koreans and Americans differ in proficiency in informal mathematics, if Korean children start off with an advantage in this area, and if their informal mathematics is different from that of Americans. The study also examined: possible cultural differences in the understanding of and performance in formal mathematics (which involves the understanding of written symbolism, algorithms, and mathematical principles, and constitutes the focus of primary mathematics instruction); when this difference (if any) appears; and whether Korean children show a particular advantage in the area of rote mathematics. Subjects were 315 Korean and 538 American boys and girls from each of five age levels ranging from 4.5- to 8.81-years-old. Two of the findings reported (obtained from test items administered during individual interviews specified in the Test of Early Mathematical Ability) are these: Korean children show superior performance in formal mathematics within the first few years of school and there was no head start for Korean children in early mathematical thinking. Factors which may explain these and other results and implications for mathematics instruction are addressed. (JN)

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The Development of Informal and Formal Mathematical Thinking in Korean and American Children

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Cross-national studies have shown that the mathematics achievement of school age children in the United States lags behind that of children in Asian countries such as Japan and Taiwan (Stigler, Lee, Lucker, and Stevenson, 1982), and in European countries such as Belgium and Finland (Husen, 1967). As Stigler at al. (1982) have shown, classroom practices and cultural attitudes toward schooling play important roles in producing the observed differences between Oriental and American children. Oriental children undergo a more intensive process of schooling than do Americans. Thus, in Japan and Taiwan time on task is longer and more homework is assigned than in the United States. Also, Japanese and Taiwanese parents seem to place heavier stress on the importance of schooling, and to exert stronger pressure on their children than do American parents to perform well in school.

Little is known about cognitive factors that might also contribute to cross-national differences in mathematics achievement. This paper draws on recent research and theory from developmental and cross-cultural psychology to examine cognitive factors possibly involved in achievement differences between Orientals-- specifically Koreans-- and Americans. First we determine whether Korean children,

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like those in Japan and Taiwan, exhibit superior performance in elementary arithmetic. If, as we expect, they do, then two issues arise. One is the extent to which Korean children's superior achievement in mathematics might be related to an early advantage in informal mathematical thinking. A second issue concerns the extent to which the observed superiority reflects "rote" activity or deeper understanding.

In regard to the first issue, recent research has shown that mathematical thinking begins well before children enter school (Ginsburg, 1982a,b, 1983). Within the first five years of life, and before they are taught written mathematics in school, young children acquire proficiency in various notions and skills which do not involve written symbolism, for example judgements of relative magnitude and addition by counting. Gelman and Gallistel (1978) have shown that even 2- and 3-year-olds may develop preliminary notions and skills of addition and subtraction. By 4 or 5 years of age, the child is relatively proficient in "practical arithmetic" (Ginsburg, 1982a,b; Carpenter, Moser, and Romberg, 1982). Thus, the 4-year-old may know that 5 is greater than 3 and may be able to add 5 and 3 objects mentally, for example by "counting all" ("5 and 3 is 1, 2, 3, 4, 5, and then 6, 7, 8"), even though he or she cannot deal in any way with written representations of these problems. Children seem to acquire counting related concepts and skills through such informal processes as spontaneous interactions with the environment, imitation of adults, and watching TV. Moreover, cross-cultural research shows that there is widespread occurence of informal skills across social classes, racial groups, and cultures. In Western societies, black and white pre-school

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children display few important differences in key aspects of informal mathematical thought (Ginsburg and Russell, 1981). In traditional African societies, even illiterate children in the rural setting possess informal skills like counting and mental addition (Ginsburg, Posner & Russell, 1981b).

The fact that basic proficiency in informal mathematics seems to be common across social class, race, and culture (Saxe and Posner, 1983) does not necessarily preclude the possibility that Orientals generally and Koreans in particular are advanced in such concepts and skills. Perhaps one reason for Korean children's early school success is superior informal mathematical thinking beginning at the pre-school level. This superior ability, one may hypothesize, provides Korean children with a "head start" enabling them to assimilate later school mathematics more effectively than do American children.

There are a priori reasons both for accepting and rejecting this possibility. Arguing for the hypothesis is the fact that the Oriental counting system, shared in Korea, China, and Japan, is more regular than the English and hence should be easier for young children to learn. The Oriental number system does not involve the irregularities of counting from "eleven" to "twenty" as the American system does. Instead, these numbers are rendered as "ten-one, ten-two, ten-three...two-ten". Moreover, the Oriental counting system has a more regular "decades" system than does the English: thus, "ten, two-ten, three-ten, ...nine-ten." Miller's (1984) report that Chinese children at the ages of 4, 5, and 6 count to a significantly higher limit than do their American peers supports the hypothesis that the Oriental

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counting system is easier to learn than the English language system.

Arguing against the hypothesis are two considerations. First, particularly in Korea, children must learn to use two kinds of counting systems simultaneously. Both are similar in structure but one is more formal than the other. The more formal is typically used in written work in school and for counting larger numbers. The less formal is generally used in everyday situations and for smaller numbers. Young children might experience difficulty in acquiring a dual counting system of this type. Second, Korean parents generally give little intellectual stimulation to their children at home before they enter school. No systematic teaching of addition and subtraction skills or concepts is given before children enter primary school; this is also true in Japan (Hatano, 1980). In particular, Korean society has traditionally looked down upon commercialism and related arithmetic activity. Thus, many Korean parents regard as indecent such activities as the training of preschool children in the counting of money or in calculations regarding it. This neglect of number is even reflected in the Korean language. For example, nouns make no distinction between singular and plural, unless it is absolutely necessary to do so. The Korean discouragement of activities relating to informal arithmetic might result in relatively poor proficiency in this area.

In view of these considerations, the present study investigates several aspects of informal mathermatics in Koreans and Americans: Do the groups differ in proficiency in informal mathematics? Do Korean children start off with an advantage in this area? Is their informal mathematics different from Americans'?

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The present study also examines possible cultural differences in formal arithmetic, which involves the understanding of written symbolism, algorithms, and mathematical principles, and constitutes the focus of primary mathematics instruction. While Korean children's achievement in this area is likely to be greater than that of American's, it is possible that the *nature* of Korean children's academic performance is different from Americans'. For example, perhaps Oriental children can memorize material better than Americans but do not understand it as well and even are not as creative as Americans (Jaquish and Ripple, 1984). In this view, Orientals' higher achievement scores may be partially attributable to success on specific "rote" items like number facts.

There is little evidence directly relevant to this hypothesis. Drawing on standard achievement tests, Vernon (1982) proposes that Chinese and Americans may differ in rote vs. conceptual aspects of mathematical thinking. But other cross-cultural research suggests that children's understanding of formal mathematics is similar across cultures. Little difference has been reported on the concepts, procedures, strategies, and types of errors in addition and subtraction calculation between African and American children (Ginsburg et al., 1981a; Posner, 1982). At the same time, this does not preclude the possibility that Korean children emphasize some aspect of formal mathematics (e.g., rote number facts) more than another (e.g., conceptual understanding).

The present study attempts to address this issue by asking: Are

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there differences between Koreans and Americans in the nature of their understanding of and performance in formal mathematics? When does this difference, if any, appear and what is it like? Do Korean children show a particular advantage in the area of rote mathematics?

METHOD

Subjects

Subjects in this study were 315 Korean children and 538 American children, boys and girls, at each of five age levels. The mean ages for the Korean subjects were 4.75, 5.78, 6.82, 7.84, and 8.81, and for American subjects they were 4.50, 5.57, 6.55, 7.56, and 8.45. The Koreans are two or three months older at each age level since their academic year starts in March, several months earlier than in the United States. These age groups will hereafter be referred to as 4-, 5-, 6-, 7-, and 8-year-olds. The numbers of boys and girls at each age level are given in Table 1. Half of the 4- and 5-year-old Korean children were sampled from two different public child care centers, and the other half from two different private child care centers. Children in the two public child care centers are generally from lower-class families in the suburban areas of Seoul. These centers are free and relatively poor both in teaching and facilities. On the other hand, the two private centers are attended by children from more affluent, upper-middle-class families in Seoul, and use the fees paid by students' families to maintain good educational environments. The children at the age levels of 6, 7, and 8 were sampled from two primary schools located in an area of lower-middle-class residents in the city of Busan. (Determinations of social class membership were made by the

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Korean Bureau of Education.)

Insert Table 1 about here

American subjects were part of the standardization sample of the Test of Early Mathematics Ability (TEMA) (Ginsburg and Baroody, 1983). They were sampled from schools in twelve states across the country. Approximately three fourths of the subjects were city residents and four fifths of them were white. About half were from white-collar families and half from blue-collar families. There were more male than female subjects in the American sample. This should not cause concern, however, because previous research has repeatedly shown that there are few sex differences in mathematical ability in the preschool and early school years (Fennema, 1974; Maccoby and Jacklin, 1974; Stigler et al., 1982). Also in analyzing the data the imbalance between the sexes was controlled by statistical procedures.

It is very difficult to arrange neat social class comparisons between Koreans and Americans, partly because the cultures are so different and partly because the Korean Gross National Product is much lower than the American. We make no claim, therefore, that social class is perfectly comparable between Korean and American subjects. All we can say is that the American subjects represent a reasonable social class spread at all age levels and so do the Korean subjects at ages 4 and 5. At ages 6, 7, and 8 the Koreans are generally lower-middle-class by Korean standards.

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Task

The task used in this study was the TEMA (Ginsburg and Baroody, 1983), constituted of 50 items which were chosen to measure important aspects of early mathematical thinking and were often derived from methods originally employed in the research of Ginsburg and his colleagues (e.g., Ginsburg and Russell, 1981). The TEMA contains 23 items intended to measure informal mathematics (activities which do *not* involve written symbolism) and 27 items of formal mathematics (activities involving the written, symbolic mathematics taught in school). Informal mathematics items involve three different kinds of sub-skills: concepts of relative magnitude, involving the ability to judge the relative size of spoken numbers and the distance between numbers on a mental number line; counting, involving both the ability to produce number words in the standard sequence and in others (e.g., backwards) and to enumerate objects; and calculation, involving the ability to add concrete objects and to perform mental addition and subtraction. Formal items involve four kinds of sub-skills: knowledge of convention, involving the fundamental skills of reading and writing numerals; number facts, involving a quick and accurate response to relatively small problems in addition, subtraction, and multiplication; calculation, involving both accuracy and strategy in written addition and subtraction; base-ten concepts, including the ability to manipulate currency of different values, and the ability to add and subtract multiples of ten.

For Korean children, test items were translated into that language by the first author, a native speaker of Korean. On occasions when the

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content of an item was not congruent with the Korean language or number system, it was modified in minor ways to fit that language or system without changing the basic intention of the item.

Procedure

Subjects were individually tested in a structured and standardized interview strictly following the procedure described in the TEMA manual. For Korean primary school children, the interviews were conducted by four primary school teachers. The teachers were thoroughly trained beforehand to understand and follow the TEMA manual procedure. For Korean preschool children, four graduate students majoring in psychology conducted the interviews. These interviewers were well trained by a Korean professor of psychology with great experience in testing children. For American subjects, interviews were conducted by well-trained psychologists, educators, and graduate students.

The procedure and order of presentation of test items was as specified by the TEMA manual. Items are given in order of increasing difficulty. If a child did not give correct response to five items in succession, testing was stopped on the assumption that there was little chance of further success. If the subjects in the younger age groups showed signs of boredom, fatigue, or distraction, the interview was halted and continued the next day. Several of the pre-school children selected as subjects at the start were replaced by other children because they could not concentrate on the interview. Individual testing took about 25 minutes on the average. Except for the items that require a time limit, subjects were given as much time as they needed to deliberate or formulate responses.

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Scoring and Analysis

Children received one point for every item answered correctly: therefore 50 was the maximum possible total score, 23 for informal and 27 for formal items. The maximum score for each sub-skill in informal mathematics was 4 for relative magnitude (IRM), 14 for counting (IC), and 5 for calculation (ICAL). For sub-skills in formal mathematics the maximum score was 6 for knowledge of convention (FCV), 9 for number facts (FNF), 7 for calculation (FCAL), and 5 for base-ten concepts (FBT). Scoring of individual items was carried out using the detailed instructions given in the TEMA manual.

Three-way ANOVAs (Analyses of Variance) by culture, age, and sex for unbalanced data were performed on various TEMA scores. *t* -tests were used for the analyses of differences between cultures within age groups, and Duncan's Multiple Range Tests were used for post hoc analyses between age groups. Cultural differences in performance on individual items (e.g., "rote" vs. principle) were analyzed by Chi-square tests. Cultural comparisons of the rank order of difficulty of items were carried out by means of correlations.

RESULTS

After determining whether Korean children exhibit superior performance in formal mathematics, we turn to the issues of whether they begin with a head start in informal mathematics and whether their formal mathematics is qualitatively similar to Americans'.

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Cultural differences in formal mathematics achievement

We begin by providing an overview of the results by presenting, in Table 2, mean scores of overall performance on the TEMA for all the age groups and for both cultures. A three-way ANOVA by culture, age, and sex revealed significant effects for culture, F (1,833)= 55.32, p <.0001, with Korean children doing better overall, and for age, F (4,833)= 287.96, p < .0001, with children performing better with increasing age. There were no significant sex effects. There was a significant interaction effect for culture by age, F (4,833)= 16.69, p < .0001. t -tests within age group showed that the overall performance level of American children was significantly higher than that of Korean children at the age levels of 4 and 5 years (t = 3.56 and 4.53 respectively, p < .0001 for both). By the age levels of 7 and 8, however, the overall performance level of Korean children was significantly higher than that of American children (t = 4.35 and 10.07 respectively, p < .0001 for both). There was no significant difference between the two groups at the 6 year level. Duncan's Multiple Range Tests for post hoc analyses between age groups revealed significant increases in performance between all the age groups, except for the age level between 7 and 8 for American children. For Korean children, however, there were significant increases between all the age levels.

Insert Table 2 around here

The interaction effect for culture by age can be examined further

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by considering both informal and formal TEMA scores, as can be seen in Figure 1. It is clear that the reversal of performance levels between the two cultures occurs between the ages of 6 and 7 when Koreans receive higher scores in both informal and formal areas. Korean children achieve high scores in both informal and formal mathematical thinking at 7 and 8 years. For American children, however, the gap between the two types of thinking remains wide; American children at both ages 7 and 8 show poor performance in formal mathematics.

Insert Figure 1 around here

Mean scores in overall formal mathematics are shown in Table 3. A three-way ANOVA by culture, age, and sex revealed significant effects for culture, F (1,833)= 144.06, $p < .0001$, with Korean children performing better than Americans; for age, F (4,833)= 289.48, $p < .0001$, with older children doing better; and for the interaction of culture by age, F (4,833)= 18.80, $p < .0001$. t -tests within age groups showed that there was no significant difference in formal mathematics between the two cultures at the age levels of 4, 5, and 6. However, at the age levels of 7 and 8 the performance levels of Korean children were significantly higher than those of American children (t = 4.47 and 10.38 respectively, with $p < .0001$ for both).

Insert Table 3 around here

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Duncan's Multiple Range Tests for post hoc analyses indicated no significant increases in performance between the age levels of 4 and 5 for both cultures. This shows that, despite attempts at training in some preschools, formal mathematical thinking as defined by the TEMA develops very little between the ages of 4 and 5 in both cultures. At the same time, Korean children's superiority in formal mathematics was very clear by the age of 7. Between 7 and 8 years of age, American children show a plateau in formal mathematical thinking, just as they did in informal mathematics at the same period.

In brief, the data show clearly that Korean children show superior performance in formal mathematics within the first few years of school.

Cultural differences in informal mathematics

Mean scores in both overall informal mathematics and in informal sub-skills are shown in Table 4. In overall informal performance, a three-way ANOVA by culture, age, and sex revealed a significant effect for age, F (4,833)= 196.06, $p < .0001$, with older children exhibiting better performance. There was no significant main effect for culture, although there was a significant interaction effect for culture by age, F (4,833)=12.69, $p < .0001$. t -tests within age groups showed that the performance levels of American children at the ages of 4, 5, and 6 were significantly higher than those of Korean children (t = 4.73, 6.03, and 2.69 and $p < .001$, .001, and .01 respectively). By contrast, at the age levels of 7 and 8, the performance of Korean children significantly exceeded that of American children (t = 3.27 and 7.95 and $p < .01$ and .001 respectively). There was no significant effect

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for sex.

An examination of Table 4 shows that the performance levels of American children were higher than those of Koreans in all the sub-skills of informal mathematics at the age levels of 4 and 5. By the age level of 8 the performance level of Korean children surpassed that of Americans in all the sub-skills of informal mathematics.

Duncan's Multiple Range Tests for post hoc analyses revealed significant increases in performance between all the age groups in both cultures except for the age level between 7 and 8 for American children. Considering both the mean scores and t -values, the age levels of 6 and 7 seem to be the transitional period during which the performance of Korean children begins to surpass that of Americans.

Post hoc analyses revealed that for Korean children there were significant increases in performance between all the age groups in all the informal sub-skills. (One exception involved informal counting between the ages of 7 and 8. This can, however, be attributed to the ceiling effect at the age of 7.) For American children between the ages of 7 and 8, there was no significant difference in performance levels in all the informal sub-skills.

In short, the performance level of American children in informal mathematics at the age level of 4 and 5 was significantly higher than that of Korean children. The American children's superiority was revealed in all the sub-skills of informal mathematics. There was no head start for Korean children in early mathematical thinking. By the

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age of 7 or 8, the Korean children surpassed their American counterparts.

Insert Table 4 around here

The nature of formal mathematics

Table 3 shows the means of the formal mathematics sub-skills. t -tests between cultures within age groups revealed that at the age levels of 4, 5, and 6 there were no significant differences between the two cultures in almost all sub-areas of formal mathematics (except for number facts at the 6 year level where American children showed significantly higher performance, with $t = 3.33$. $p < .0001$). But at the age level of 7, Korean children exhibited significantly higher scores than American children in number facts ($t = 3.92$, $p < .001$) and in calculation ($t = 6.24$, $p < .0001$). At the age of 8 this superior performance of Korean children appeared in all the sub-areas of formal mathematical thinking.

Chi-square tests for the analysis of cultural differences for both "rote" items and principl and process items are shown in Table 5. Korean children were superior in all areas, but especially in principle and process items. American children were extremely poor in written subtraction calculation.

Insert Table 5 around here

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There was a high and significant correlation between the average ranks of Korean and American children on all TEMA items (rho= .97, $p < .0001$). Essentially the same results are found if one computes separate correlations for the average ranks of formal items and informal items. This shows that, despite the differences in performance levels, the two cultural groups master the different items in roughly the same order; apparently, the relative difficulty of the various items is highly similar for members of both cultures.

In brief, Korean children's superiority appeared in every sub-area of formal mathematics at the age of 8: both in rote items (e.g., number facts) and in conceptual items (e.g., base-ten concepts). American children were particularly poor both in accuracy and in procedures of calculation. Despite different performance levels the two cultural groups showed a similar formal mathematics.

DISCUSSION

We begin the discussion with a consideration of the clear fact that Korean school children perform at a higher level than do Americans. Then we turn to Korean preschool children's relatively poor performance in informal mathematics and speculate on the reasons for it. Finally we discuss the nature and causes of Korean school children's superior performance at both formal and informal mathematics and offer some speculations about why American children do not perform as well as they could.

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Differences in formal mathematics achievement.

The results of the present study clearly show that by the ages of 7 and 8 the performance level of Korean children surpasses that of American children by a significant amount in both formal and informal mathematics. Whereas Korean children's performance increased consistently after the age of 5, American children showed no significant increases in performance between the ages of 7 and 8, even though their performance levels at those ages was still far below ceiling. Note that at the primary school level, Koreans were if anything at a somewhat lower social class level than the Americans but still did better. The notion of social class is not important in explaining these results.

The results are generally consistent with Stigler et al's (1982) data concerning formal mathematics. According to Stigler et al., the performance level of 6-year-old American children is significantly lower than that of Japanese and Tawain children at the same age. In the present study Korean children's superiority did not begin to appear until the age of 7. Perhaps this can be explained in part by the fact that at the first grade level Korean schools place more emphasis on language than on mathematics (Song, 1984). Are the Korean children slower than the Japanese and Taiwanese? It is hard to make precise comparisons between our data and Stigler's since the two studies use different test items. While it is clear that American children in the early years of school lag behind Japanese, Chinese, and Korean peers in formal mathematical achievement, further research is necessary to determine whether the difference emerges earlier in Taiwan and Japan

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than it does in Korea.

Preschool differences in informal mathematical thinking

The results of this study showed that, contrary to expectation, the performance levels of American children were significantly higher than those of Koreans at the age levels of 4 and 5 in all the sub-skills of informal mathematics. While not displaying severe deficiencies in informal mathematics, Korean children clearly lag behind American children during the preschool years and do not seem to benefit from an advantage in early mathematical thinking.

Several factors may be suggested to explain these results. First, the pattern of parent-child interaction during preschool ages in Korea is emotionally, rather than intellectually oriented. Since many Korean parents believe that education begins only when the child enters school, they do not make active attempts to provide their children with intellectual stimulation during the preschool years. This is particularly true in the mathematical area: Korean children have few opportunities to engage in counting and to make numerical comparisons involving toys, money, and other objects. In traditional Korean society, an early concern with money and with counting has been regarded as indecent. These attitudes are widespread although recently they have been changing among higher income parents. This discouragement of children's intellectual work at home may result in Korean children's weaker performance in informal mathematics.

Second, young Korean children's attempt to learn a dual system of counting might interfere with the acquistion of informal mathematics.

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The necessity to learn two different, even though structurally similar, counting systems in the early preschool years might produce a temporary cognitive overload, or confusion, which would make difficult the concurrent attempt to master such skills as counting, relative magnitude, and mental calculation. There is only so much young chidren can learn at once. This difficulty of the Korean system is in contrast to the experience of Chinese children who learn a system with only one regular way of counting (Miller, 1984). Once mastered, however, the dual counting system may be extremely effective. Thus, the counting skill of Korean children develops very fast between the ages of 5 and 6 and arrives at nearly maximum development at the age of 7, much earlier than that of American children. It is also possible that the dual counting system exerts facilitating effects on other aspects of mathematical learning, for example in the area of informal calculational skills where Korean children at ages 7 and 8 achieve a higher level of proficiency than do their American peers.

Third, deficiencies in Korean preschool education might delay the acquisition of early mathematical skills. While the development of informal skills does not depend on formal instruction, it is facilitated by experience in rich environments. Thus, while often lacking in formal education, the Dioula of the Ivory Coast grow up in an environment offering rich experience with numerical calculations as employed in commerce; this experience seems to produce informal calculational skills of an advanced nature (Ginsburg, Posner, and Russell, 1981b). As we have noted, Korean families do not seem to provide preschool children with rich experiences of this type. Neither do the Korean preschools. Even though the rate of attendance in

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preschool now amounts to 28.3% of appropriate age children in Korea (Annual Report of Korean Ministry of Education, 1984), many of the preschools are relatively unstimulating; the better ones are attended mainly by small numbers of upper class children in urban areas. Besides this, the major objectives of preschool education in Korea, as in Japan (Hatano, 1980), lies in the learning of appropriate social behavior patterns, not numbers or letters. In brief, the deficiencies of Korean preschool education in terms of intellectual stimulation may contribute to the late development of informal mathematical thinking.

Several factors which do not seem to explain the Koreans' relatively low performance in informal mathematics are discussed next. Could Korean children have done poorly because of a lack of familiarity with test taking or because of inadequacies in the TEMA? While these possibilities cannot be completely eliminated without a good deal of further research, they seem unlikely. Children's lack of experience with taking tests does not necessarily produce poor performance, especially when sensitive testers are involved. Thus, Ginsburg, Posner, and Russell (1981b) showed that illiterate members of the Dioula group, children and adults, who are quite unfamiliar with testing, nevertheless demonstrated considerable competence in various aspects of informal mathematics. In the present research, the investigators went to great lengths to train the testers to put children at ease and elicit their best efforts. Despite these precautions, further research is necessary to determine whether Korean preschool children possess poor test taking skills and if so whether they contribute to low performance.

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Can inadequacies in the TEMA account for Korean children's poor performance? That seems unlikely. Test items were translated and revised to fit Korean ways of thinking and the Korean number system. Further, many of the items comprising the TEMA were derived from procedures successfully employed in earlier research which demonstrated unsuspected competencies in lower-class preschool children in the United States (Ginsburg and Russell, 1981).

Can factors associated with social class account for the observed cultural differences? First, as mentioned above, social class may not have the same meaning in different cultures. It seems impossible to determine whether low SES, for example, in Korea is the "same" as low SES in the U.S. Second, putting this difficulty aside, we can note that at the preschool level, lower and middle class children formed about half the sample in both the Korean and American groups, so that class alone cannot be responsible for the observed cultural difference.

Qualitative differences in mathematical thinking

In all sub-skills of formal mathematics Korean children's performance was higher than that of American children at the age levels of 7 and 8. Korean children were superior both in "rote" items (number facts), and in concept and principle items (base-ten concepts and calculation). This result is consistent with Stigler et al's data (1982) indicating that children in Taiwan and Japan were skilled at problems involving application of mathematical principles. Also, despite differences in performance, the two cultural groups showed the same order of difficulty in mastering the items. Thought in the two cultures seems to be similar, at least at the age levels studied. It is

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not the case that in the early years of school Oriental children emphasize the "rote" aspect of formal mathematics more than conceptual understanding. Of course, further research is necessary to determine whether this is true in the higher grades as well.

In brief, Korean children's school matnematics achievement does not appear to be qualitatively different from Americans'. This result confirms the earlier finding of Ginsburg, Posner, and Russell (1981a) showing that Africans' school ma'hematics is similar to Americans'. One explanation for this is that, in general, thought processes in diverse cultures are basically very similar to one another. Hence, when children in those cultures encounter what is essentially a common body of knowledge, namely arithmetic, they assimilate and learn it in basically the same fashion, with the result that knowledge of formal mathematics is similar across cultures.

Reasons for Korean children's success and American children's failure

We have seen that Korean children's superior performance in school arithmetic cannot be explained by a head start in informal mathematics. Superior performance at the preschool level is not a prerequisite for later school achievement. In this sense, preschool is not a "critical period" for later school success. We have also seen that Korean children's school success is not illusory: they do not succeed only because of rote memorization; their thought does not seem to be qualitatively different.

Why do Korean children perform so well? The reasons seem to involve environmental-cultural factors. Several aspects of schooling

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seem to be involved. First, the amount of time devoted to mathematics instruction in Korea is greater than in the U.S. The number of days in a week that children attend at school in Korea is six, the same as in Japan and Taiwan, and more than in the U.S. According to Stigler et al. an average of 25% of classroom time in Japan and 17% in Tawain is spent in mathematics learning in the first grade. In Korea, approximately 18% of classroom time is alloted to the study of mathematics (Korean Ministry of Education, 1982a). If independent study hours alloted to mathematics are included, the actual classroom time in Korea approaches 30% (Song, 1984). By contrast, in the U.S. (Minneapolis) 14% of the time is allotted to mathematics.

The Korean schools seem to operate in an intense fashion despite the fact that the average class size is 58, which is larger than in Japan, Taiwan, and the U.S. Curiously, large class size may contribute to the success of Korean classrooms. Well-disciplined behavior is seen as a necessity in large classrooms. Further, in Korea, large class size seems to result in a productive competition among children; also parents and teachers put pressure on children to do well in their studies <u>despite</u> the large class size. All these factors, together with respect for and obedience to teachers, seem to promote effective learning in large classes. Such an outcome for large class size would hardly be predicted in American society.

Second, Korean teachers seem to be relatively knowledgeable in the field they are teaching. Teachers often conduct informal research projects in their classrooms. The Ministry of Education requires teachers from primary school to college level to carry out a research

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project and submit a report on it each year. Winning an award in the nation-wide competition for good research projects is one of the most important factors in the promotion of teachers. Many primary school teachers have a major interest in mathematics as a personal research topic. Teachers are eager to read relevant books and articles and to seek assistance from experts in the field. This unique in-service teacher-training system encourages Korean teachers to maintain and update their substantive knowledge and competence in the field of mathematics education.

Third, the curriculum in Korea, as in Japan (Hatano, 1980), is centralized and controlled by the Ministry of Education. Particularly in the primary school grades, teachers adhere strictly to a very well-organized curriculum guide issued by the Ministry of Education. This centralization of curriculum might contribute to raising the average achievement level, although at the same time it may risk inhibiting the progress of some gifted children.

Also, parents in Korea place great value on their children's successful school achievement. Parents convey positive attitudes toward education and expect their children to do well. Most parents in Korea are aware that getting into "the best" college leads to success in adult life-- this is the "folk theory of getting ahead" (Ogbu, 1978). Also they realize that mathematics scores are frequently a decisive factor in college admission and hence encourage success in this area particularly. Further, the time spent by middle and upper SES parents to help their children do homework, particularly in mathematics, is great. In brief, both schooling and parental attitudes and practices

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might be responsible for the superior performance of Korean children in early formal mathematics.

Two caveats: while Korean children perform well in the first few years of school, we have little information concerning what happens after that point. It is conceivable that the efficiency of the Korean system eventually results in some unanticipated and undesirable outcomes, like high-school students who are overly pressured and too narrowly focussed on their work. Also, the content of the Korean curriculum seems to move too quickly into formal, symbolic systems without paying sufficient attention to informal concepts and concrete referents. This might eventually result in a deficient grasp of some basic concepts and principles, despite advanced achievment at the outset.

American children exhibit relatively poor performance in school mathematics despite an initial advantage in informal mathematics. There does not appear to be any fundamental cognitive reason why Americans could not perform more effectively in school. The reasons for their relatively poor performance appear to be educational and cultural. As Stigler et al suggest, shorter time devoted to instruction in mathematics, less homework assigned, and weaker pressures from parents and teachers may contribute to this result. Also, American teachers often seem to be frightened of mathematics, tend to avoid it, and have low expectations for their students' success in this area. American parents may not value, stress, and facilitate educational achievement as strongly as they might. Other explanations particularly relevant to the failure of American minority children are discussed in Neisser

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(1985, in press).

In conclusion, Oriental children's superior performance in early school mathematics is genuine and does not result from initial intellectual advantage. It seems to stem instead from an efficient educational system, knowledgeable teachers, involved parents, and a supportive culture.

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SUMMARY

This study sought to establish, first, whether Korean children exhibit superior levels of performance in school mathematics than do Americans. If, as expected, that is indeed the case, the research attempted to determine, second, whether an early advantage in informal mathematical thinking contributes to the superiority, and, third, whether the superior achievement is qualitatively different from Americans'. A large number of Korean and American children at age levels 4, 5, 6, 7, and 8 were given the Test of Early Mathematical Ability (TEMA) which measures both informal and formal mathematical thinking.

The results showed that at the ages of 7 and 8, Korean children do indeed exhibit superior performance in formal mathematics. Yet Korean preschool children's performance in informal mathematics is inferior to Americans'. Korean children do not begin with a "head start" in informal mathematical thinking. Lack of intellectual stimulation from parents at home, limited exposure to informal mathematical activities, the relatively poor educational environment at preschools, a cultural attitude indifferent to numbers, and a dual counting system (even though more regular) might explain Korean preschool children's relatively poor performance in informal mathematical thinking. On entrance to school, Korean children soon overcome this initial disadvantage, and excel in school arithmetic. Moreover, the results show that Korean children's performance is superior to that of American children in both mechanical and conceptual areas. Korean children do

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not succeed only because they can learn in a "rote" fashion. We attribute Korean children's relative success and American children's relative failure primarily to such environmental-cultural factors as classroom practices, teacher attitudes and skills, expectancies, and parental demands, values, and assistance.

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Table 1. Number of Subjects by Age, Culture, and Sex

		Age				
		4	5	6	7	8
Korean	Male	34	33	30	30	30
	Female	33	35	30	30	30
American	Male	83	67	84	50	53
	Female	46	46	46	25	38

Table 2. Mean TEMA Scores for All Age Levels and Both Cultures

Culture	Number of Subjects	Maximum Possible Score	Age Level of Subjects										All Ages
			4		5		6		7		8		
Korean	315	50	5.72	(*)	9.84	(*)	23.65	(*)	42.05	(*)	47.70		24.94
Americn	538	50	8.75	(*)	14.60	(*)	26.85	(*)	34.94		34.36		21.06

(*) means significant difference between adjacent age groups at $\alpha = .05$

Table 3. Mean Formal TEMA Scores for All Age Levels and Both Cultures

Type of Score	Maximum Possible Score	Culture	Age level of Subjects 4		5		6		7		8	All Ages
Overall Formal	27	Korean	1.34		2.51	(*)	8.10	(*)	20.83	(*)	24.72	11.05
		American	1.41		3.12	(*)	10.16	(*)	15.83		15.51	7.53
Formal Convention (FCV)	6	Korean	1.03	(*)	1.85	(*)	3.67	(*)	5.22	(*)	5.97	3.45
		American	1.32	(*)	2.22	(*)	4.29	(*)	5.06		5.02	3.15
Formal Number (FNF) Facts	9	Korean	0.25		0.46	(*)	2.48	(*)	7.57	(*)	8.73	3.73
		American	0.08		0.68	(*)	3.76	(*)	5.69		5.49	2.54
Formal Calculation (FCAL)	7	Korean	0.00		0.04	(*)	0.97	(*)	5.82	(*)	6.80	2.60
		American	0.00		0.04	(*)	1.46	(*)	3.31		3.36	1.20
Formal Base-ten (FBT) Concepts	5	Korean	0.06		0.16	(*)	0.98	(*)	2.23	(*)	3.22	1.27
		American	0.01		0.07	(*)	0.85	(*)	1.77		1.63	0.65

(*) means significant difference between adjacent age groups at $\alpha = .05$

Table 4. Mean Informal TEMA Scores for All Age Levels and Both Cultures

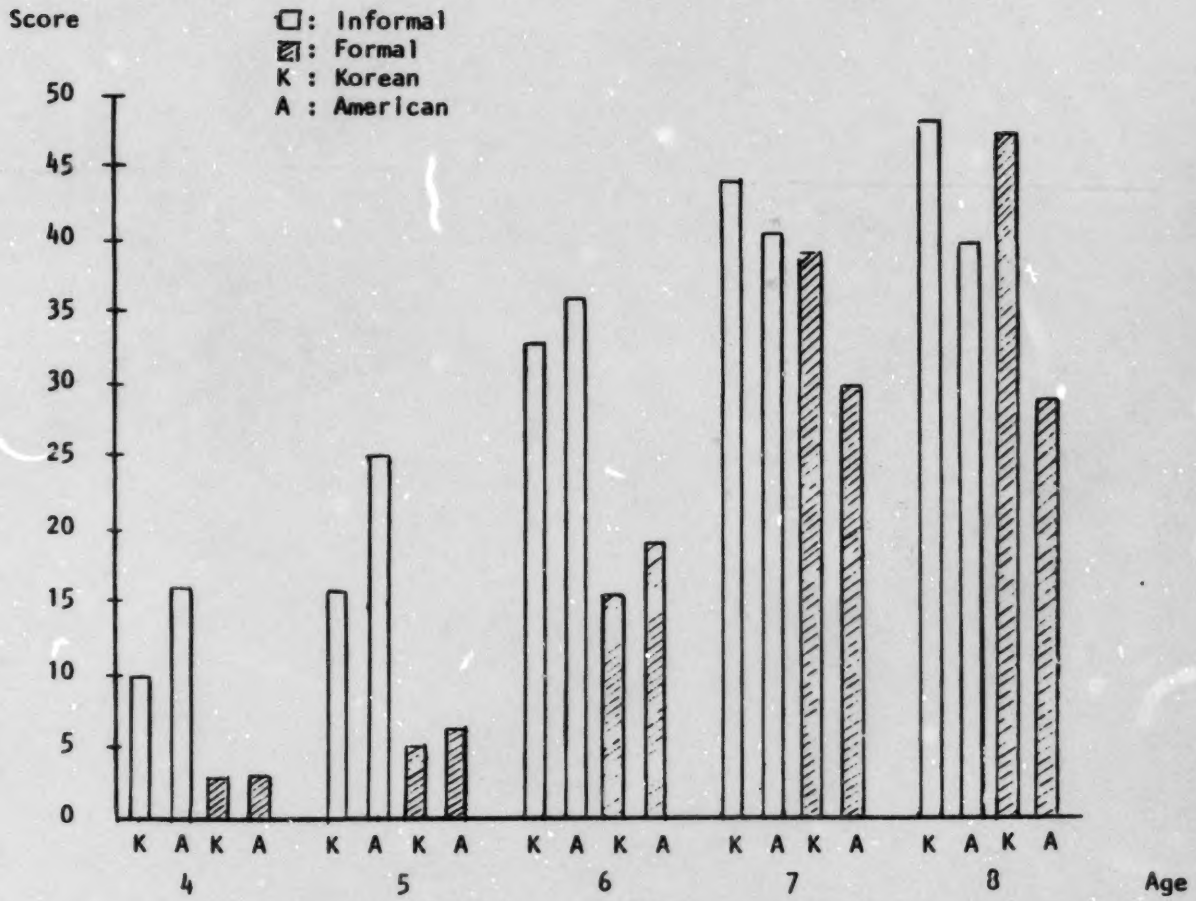
Type of Score	Maximum Possible Score	Culture	Age Level of Subjects 4		5		6		7		8	All Ages
Overall Informal	23	Korean	4.34	(*)	7.24	(*)	14.95	(*)	20.27	(*)	21.98	13.38
		American	7.34	(*)	11.45	(*)	16.41	(*)	18.49		18.33	13.31
Informal Relative Magnitude (IRM)	4	Korean	0.81	(*)	1.35	(*)	2.53	(*)	3.35	(*)	3.77	2.30
		American	1.50	(*)	2.20	(*)	2.97	(*)	3.34		3.36	2.49
Informal Counting (IC)	14	Korean	2.85	(*)	4.88	(*)	10.43	(*)	13.17		13.82	8.91
		American	4.58	(*)	7.60	(*)	11.31	(*)	12.43		12.32	8.79
Informal Calculation (ICAL)	5	Korean	0.76	(*)	1.19	(*)	2.13	(*)	3.75	(*)	4.40	2.38
		American	1.30	(*)	1.66	(*)	2.17	(*)	2.69		2.69	1.94

(*) means significant difference between adjacent age groups at $\alpha = .05$

Table 5. Chi-square Values between Cultures in Percent of Correct Responses of Both Rote and Principle Items

	Name of Item	Item Number	Korean		American
Rote Items	Convention: Reading numerals	10	80.95		79.65
	"	14	75.56		68.52
	"	23	46.67		39.30
	"	38	24.44		17.74
	Convention: Writing numerals	11	72.38		72.17
	"	24	44.76	*	34.09
	Number facts: Addition	22	46.98		41.39
	"	25	43.49	***	32.00
	"	30	36.19		28.00
	"	39	33.97	***	14.43
	Number facts: Subtraction	20	56.83		52.70
	"	29	35.56		30.43
	"	34	43.17	***	22.43
	Number facts: Multiplication	32	44.13	***	18.26
	"	48	32.70	***	8.87
Principle and process Items	Calculation: Alignment	33	40.00	***	21.39
	"	37	41.59	***	22.56
	Calculation: Written addition	28	44.76	**	33.57
	"	40	34.29	***	16.87
	"	41	35.24	***	17.57
	Calculation: Written subtraction	47	31.43	***	3.30
	"	49	37.38	***	3.65
	Base-ten: Tens in one hundred	26	51.33	***	25.39
	: Hundreds in one thousand	31	51.11	***	21.39
	: Adding and subtracting multiples of ten	35	32.38	***	17.74
		42	28.25	***	10.43
	: Smallest and largest digits	44	13.33		9.74

* $P < .01$
** $P < .001$
*** $P < .0001$



* Both scores were converted to common scale with maximum score of 50.

Figure 1. TEMA Performances in Informal and Formal Mathematics by Age and Culture